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(54) Polishing pad with uniform abrasion.

(57) A polishing pad for semiconductor wafers, having a face shaped by a series of voids (53). The voids are substantially the same size, but the frequency of the voids increases with increasing radial distance to provide a constant, or nearly constant, surface contact rate to a workpiece such as a semiconductor wafer, in order to effect improved planarity of the workpiece.

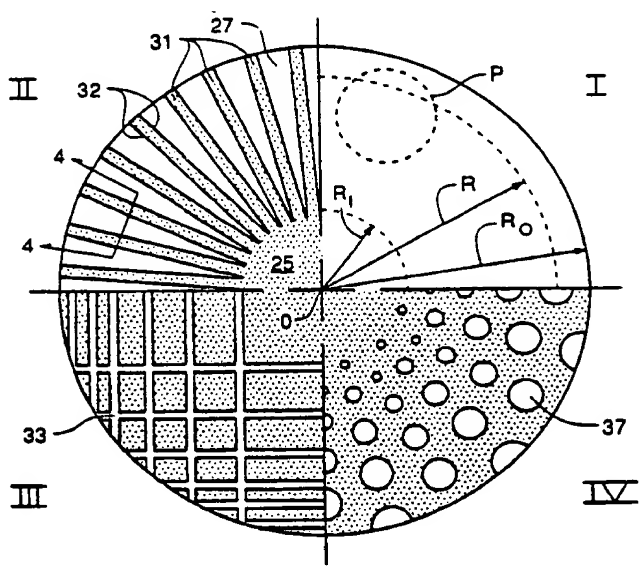

FIG. 3

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POLISHING PAD WITH UNIFORM ABRASION

BACKGROUND OF THE INVENTION

Field of the Invention

This invention relates to the grinding or polishing of a workpiece, in particular the polishing of a semiconductor wafer surface to a high degree of planarity.

Description of the Related Art

In the manufacture of integrated circuits, for example, planarity of the underlying semiconductor substrate or wafer is very important. Critical geometries of integrated circuitry are presently in the neighborhood of less than 1 micron. These geometries are by necessity produced by photolithographic means: an image is optically or electromagnetically focused and chemically processed on the wafer. If the wafer surface is not sufficiently planar, some regions will be in focus and clearly defined, and other regions will not be defined well enough, resulting in a nonfunctional or less than optimal circuit. Planarity of semiconductor wafers is therefore necessary.

Chemical and mechanical means, and their combination (the combination being known as "mechanically enhanced chemical polishing"), have been employed, to effect planarity of a wafer. In mechanically enhanced chemical polishing, a chemical etch rate on high topographies of the wafer is assisted by mechanical energy.

Figures 1a and 1b illustrate the basic principles used in prior art mechanical wafer polishing. A ring-shaped section of a polishing pad rotates at W_p radians per second (R/s) about axis O. A wafer to be polished is rotated at W_W R/s in the opposite sense. The wafer may also be moved in directions +X and -X relative to O, the wafer face being pressed against the pad face to accomplish polishing. The pad face may not itself be abrasive. Actual removal of surface material from the wafer is often accomplished by a mechanically abrasive slurry, which may be chemically assisted by an etchant mixed in with the slurry.

Figure 2 helps to clarify rotation W_W and the ring shape of the pad in Figure 1. For a generic circular pad rotating at W R/s, the linear speed of the polishing face at any given radius will vary according to the relationship $L = W \times R$, where L is in cm/s for W in R/s and R in cm. It can be seen, for example, that linear speed L_2 at large radius R_2 is greater than linear speed L_1 at small radius R_1. Consider now that the pad has a surface contact rate with a workpiece that varies according to radius. Portions of a workpiece, such as a wafer, contacting the pad face at radius R_1 experience a surface contact rate proportional to L_1. Similarly, portions of the wafer contacting the pad face at radius R_2 will experience a surface contact rate proportional to L_2. Since $L_2 > L_1$, it is apparent that a workpiece at radius R_2 will receive more surface contact than a workpiece at radius R_1. If a wafer is large enough in comparison to the pad to be polished at both R_1 and R_2, the wafer will be polished unevenly: the portions of the wafer at R_2 will be polished faster than the portions of wafer at R_1. The resulting non-planarity is not acceptable for high precision polishing required for semiconductor wafers.

Referring again to the prior art of Figure 1, a common approach by which prior art attempts to overcome non-uniform surface contact rate is by using a ring-shaped pad or the outer circumference of a circular pad, to limit the difference between the largest usable radius and smallest usable radius, thus limiting surface contact rate variation across the pad face, and by moving the wafer and negatively rotating it, relative to the pad and its rotation. The combination is intended to limit the inherent variableness of the surface contact rate across the wafer, thereby minimizing non-planarity. Such movement of the wafer with respect to the polishing pad's axis of rotation requires special gearing and design tolerances to perform optimally.

It is an object of the present invention to provide a polishing pad capable of providing a substantially constant, radially independent surface contact rate, improving planarity of a workpiece polished thereby.

Summary of the Invention

According to the invention, a polishing pad is provided, having its face shaped to provide a constant, or nearly constant, surface contact rate. One configuration is a rotatable circular pad having a face formed into sunburst pattern with nontapered rays. The sunburst pattern is coaxial with the pad's rotation.

In manufacturing the pads, the change in size of the voids across the radius of the pad is inconvenient. According to another aspect of the invention, the number of voids per unit area is increased as the radius increases, while keeping the void size constant. This results in a relatively constant abrasive surface arc length within a predetermined working area of the pad.

The increased number of voids per unit area along circumferences defined by progressively in-

creasing radii from an axis of rotation results in a relatively constant abrasion contact across a working area of the pad.

Alternate face patterns are also disclosed, each providing a nearly constant surface contact rate.

Brief Description of the Drawings

Figures 1a and 1b are elevational and side views of an illustrative prior art polishing pad implementation.

Figure 2 illustrates different linear velocities for different radii on a generic polishing pad.

Figure 3 shows different configurations for the inventive polishing pad.

Figure 4 is a cross-section along line 4-4 of Figure 3.

Figure 5 shows a preferred embodiment of the inventive polishing pad.

Figure 6 is a cross-section along line 6-6 of Figure 5.

Detailed Description of the Preferred Embodiment

Figure 3 shows different embodiments of the invention. With reference to Figures 3 and 4, a polishing pad face 25 is interrupted with voids 27. The voids 27 form the polishing pad face 25 into rays 31, each having parallel edges 32 (nontapered). Rays 31 meet each other at radius R_I, and continue outward to R_O, as shown in quadrant I.

Because rays 31 have parallel edges 32, a workpiece P that is stationary with reference to the polishing pad's axis of rotation O will experience the same surface contact rate at any radius R between R_I and R_O. Planarity across the finished surface of P is therefore obtainable without movement of workpiece P with respect to O, simply by pressing P against the pad face within the bounds of R_I and R_O.

Quadrant III of Figure 3 shows grooves 33 formed in the pad face such that a distance between any two grooves is oppositely related to the radius from O of the inner of the two grooves - that is, the distance between any two grooves decreases with increasing radius. The grooves so arranged are able to provide a constant surface contact rate between R_I and R_O. Two orthogonal series of parallel grooves are shown in quadrant III.

As shown in quadrant IV, circular voids 37 govern the pad face to achieve the same inventive effect. The voids are formed in the pad face such that the size of any void is cooperatively related to its radius from O- that is, void size increases with increasing radius.

In manufacturing the pads, the change in size of the voids across the radius of the pad is inconvenient. An alternative way to achieve the inventive effect is to increase the number of voids per unit area as the radius increases, while keeping the void size constant. As shown in Figure 5, circular voids 50 may be substantially the same size across the radius of the pad. The number of voids along a given length of arc drawn at a given radius increase sufficiently to provide a constant surface contact rate between RI and RO. Thus, a variation in void density is achieved across the pad, without changing the size of the voids.

While the voids 40 are shown as depressions, it is also possible to provide the holes as extending entirely through the pad (not shown).

As can be seen in the cross-sectional view of Figure 6, the voids 50 are depressions 53 between sidewalls 55. This leaves a surface 57 between the voids 50. By varying the density of the voids, the total surface 57 around any given circumference, defined by a constant radius R, can be established.

Likewise, a plurality of grooves can be cut so that each groove extends toward R_I, but the grooves extend from different distances from the axis of rotation O.

It should be understood that the term "polish" as used herein circumscribes abrasive activity such as grinding or polishing, by use of: slurry; abrasive grains embedded in the polishing pad face; chemical means; mechanically enhanced chemical polishing; or any combination thereof. It should also be understood that the invention has utility with workpieces of varying constituency, including semiconductors (such as silicon, germanium, and Group III-V semiconductors such as gallium arsenide), and optical materials (such as glass), among others. Further, although only five face patterns are disclosed herein, it should be understood that the invention is considered to include any polishing pad face pattern capable of providing a constant or nearly constant surface contact rate to a workpiece. As is known in the art of polishing, it is further possible to rotate the pad at a second axis to generate an orbital polishing effect, which effectively shifts the center axis O.

Claims

1. Apparatus to polish a workpiece, comprising:
   a) a polishing pad, rotatable about an axis (O) and having a face perpendicular to and coaxial with said axis (O);
   b) said face, in use, to be urged against the workpiece to facilitate polishing of same;
   c) said face shaped by a plurality of like sized voids (53); and
   d) said voids (53) having a spacing between adjacent voids (53) within a work zone between radii (R) from said axis (O) which

increases in an opposite relationship with the distance of the voids (53) from said axis (O),

whereby said face is configured to be able to provide to the workpiece a surface contact rate having a magnitude independent of radius (R) from said axis (O).

2. Apparatus to polish a workpiece, comprising:

a) a polishing pad, rotatable about an axis (O) and having a face perpendicular to and coaxial with said axis (O);

b) said face shaped by at least one series of parallel grooves, and wherein a first distance, between first and second adjacent grooves within said series of grooves, is oppositely related to a smallest radius (R_1) between said first groove and said axis (O);

c) said face, in use, to be urged against the workpiece to facilitate polishing of same;

wherein said face, by virtue of its shape, is able to provide a constant, or nearly so, surface contact rate to the workpiece for any radius (R) bounded by an inner radius and an outer radius from said axis (O), said radii being sufficiently different to accommodate the workpiece between them.

3. Apparatus to polish a workpiece, comprising:

a) a polishing pad, rotatable about an axis (O) and having a face perpendicular to and coaxial with said axis (O);

b) said face shaped by multiple, orthogonally arranged series of parallel grooves (33), and wherein a first distance, between first and second adjacent grooves (33) within said series of grooves (33), is oppositely related to a smallest radius (R_1) between said first groove and said axis (O);

c) said face, in use, to be urged against the workpiece to facilitate polishing of same;

wherein said face, by virtue of its shape, is able to provide a constant, or nearly so, surface contact rate to the workpiece for any radius (R) bounded by an inner radius and an outer radius from said axis (O), said radii being sufficiently different to accommodate the workpiece between them.

4. Apparatus to polish a workpiece, comprising:

a) a polishing pad, rotatable about an axis (O) and having a face perpendicular to and coaxial with said axis (O);

b) said face shaped by a plurality of voids (37), each having a size cooperatively related to its radius (R) from said axis (O);

c) said face, in use, to be urged against the workpiece to facilitate polishing of same;

wherein said face, by virtue of its shape, is able to provide a constant, or nearly so, surface contact rate to the workpiece for any radius (R) bounded by an inner radius and an outer radius from said axis (O), said radii being sufficiently different to accommodate the workpiece between them.

5. The apparatus of claim 1 or 4, wherein said voids (37) have round perimeters.

6. The apparatus of any of claims 1 to 5, wherein the workpiece is a semiconductor wafer.

7. The apparatus of any claims 1 to 6, wherein said surface contact rate is constant, or nearly so, for any radius (R) bounded by an inner radius and an outer radius.

8. The apparatus of claim 7, wherein said inner and outer radii are sufficiently different to accommodate the workpiece between them.

9. The apparatus of claim 1, 2, 3 or 4, wherein the workpiece is a semiconductor wafer.

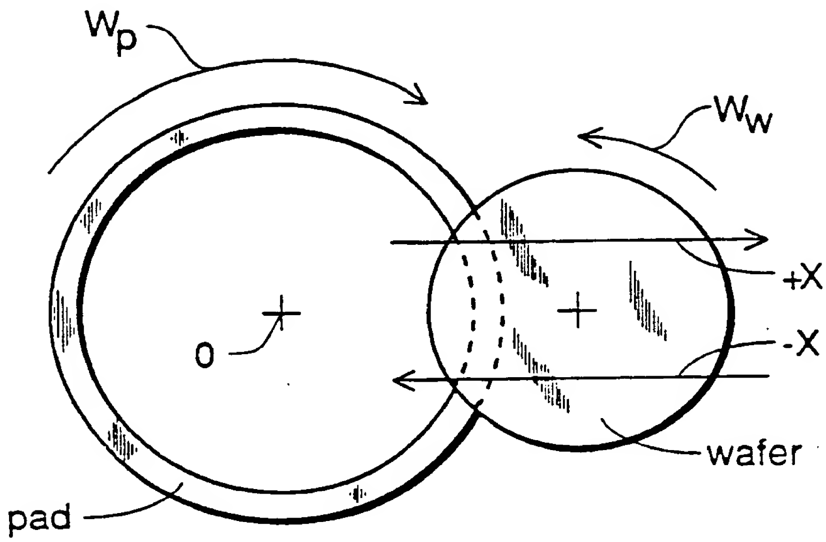

FIG. 1A
(PRIOR ART)

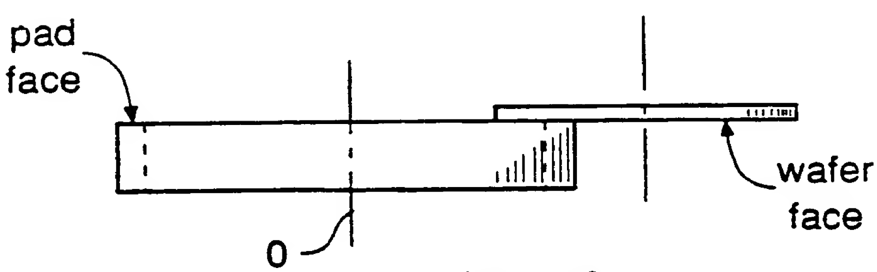

FIG. 1B
(PRIOR ART)

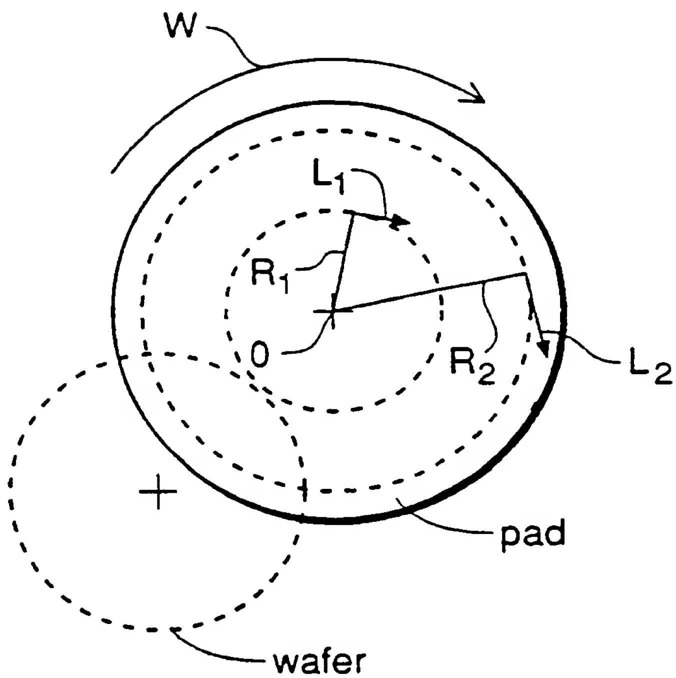

FIG. 2

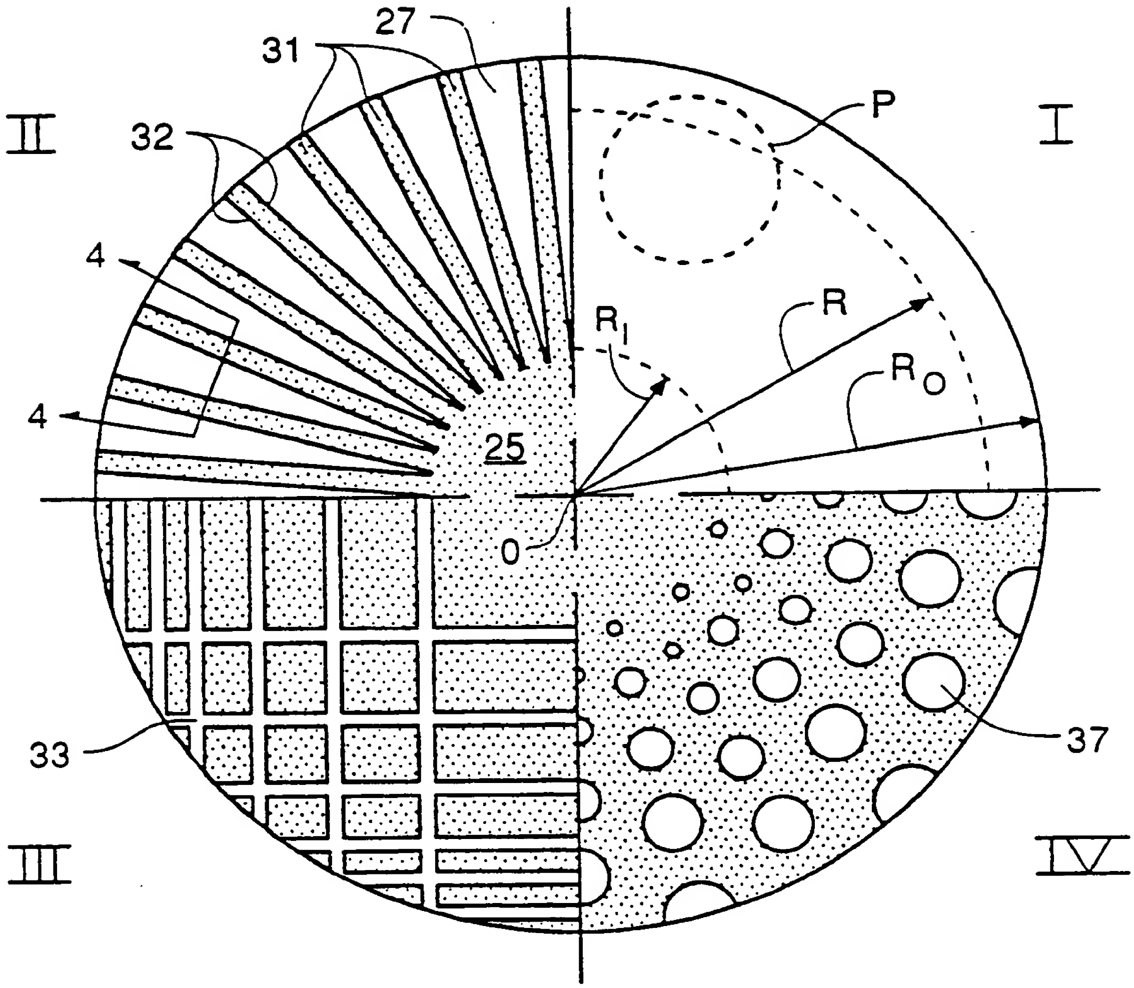

FIG. 3

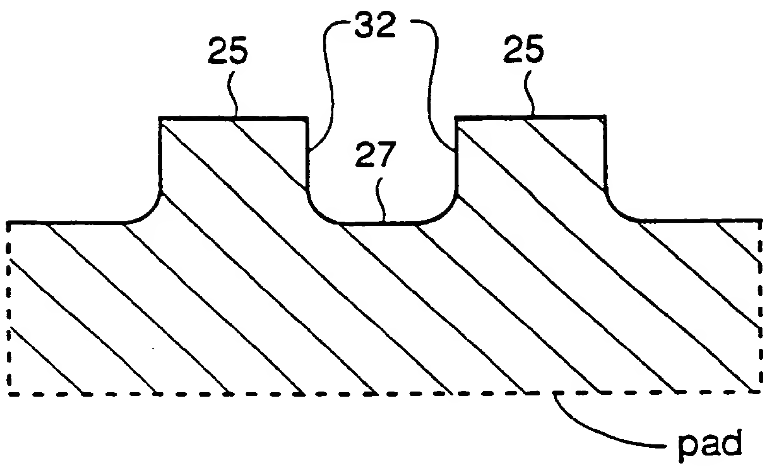

FIG. 4

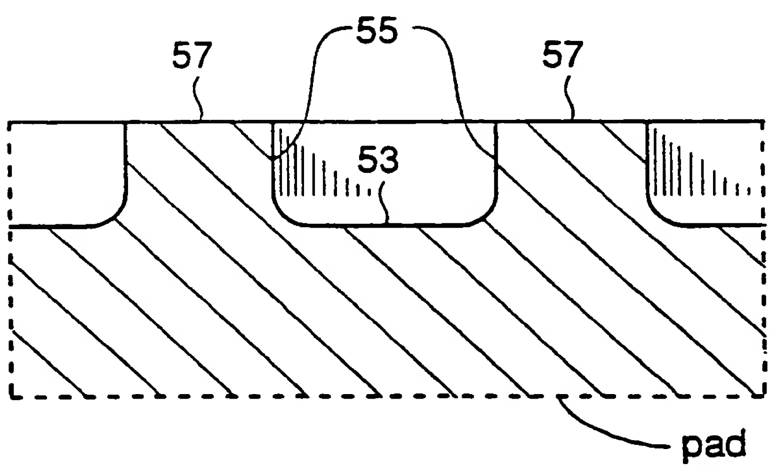

FIG. 6

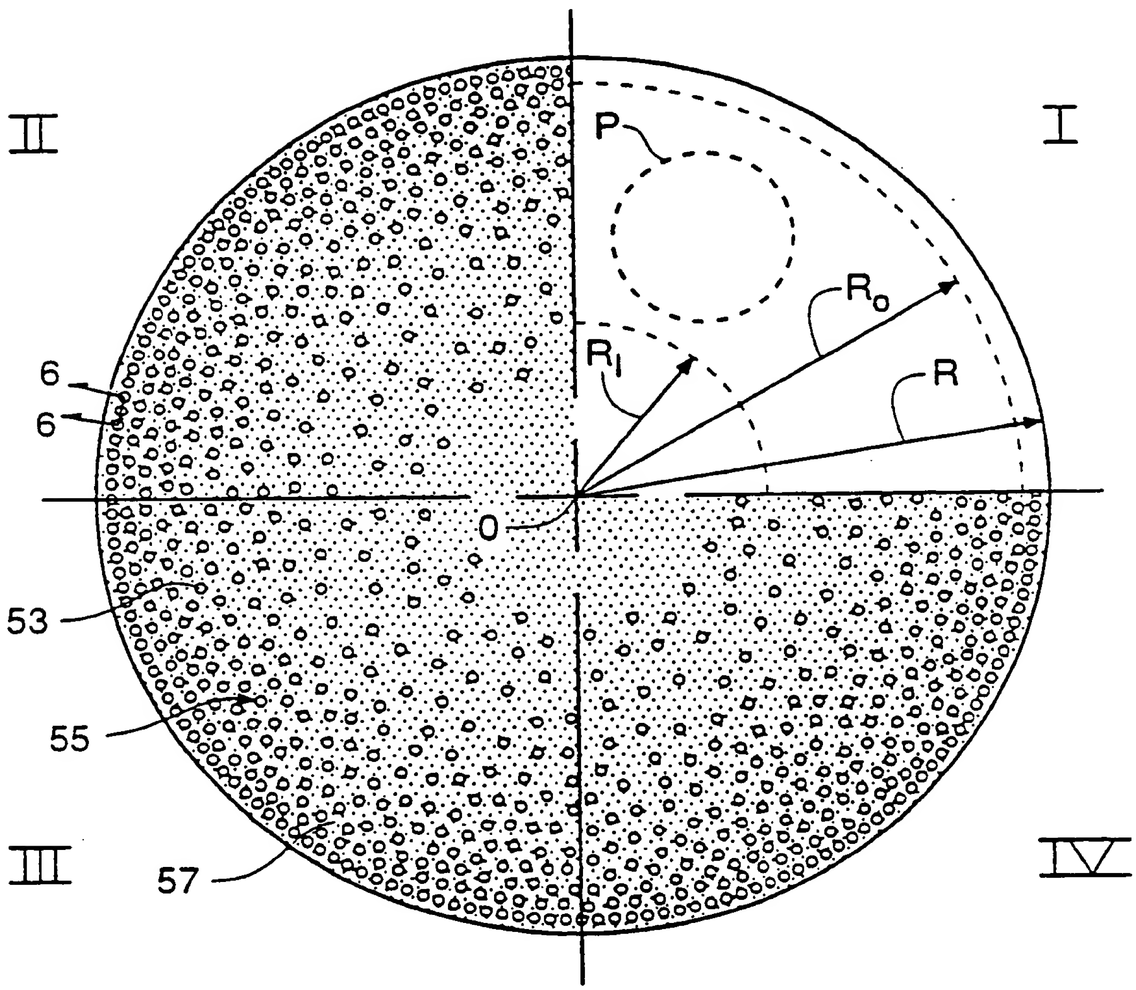

FIG. 5

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(54) **Polishing pad with uniform abrasion.**

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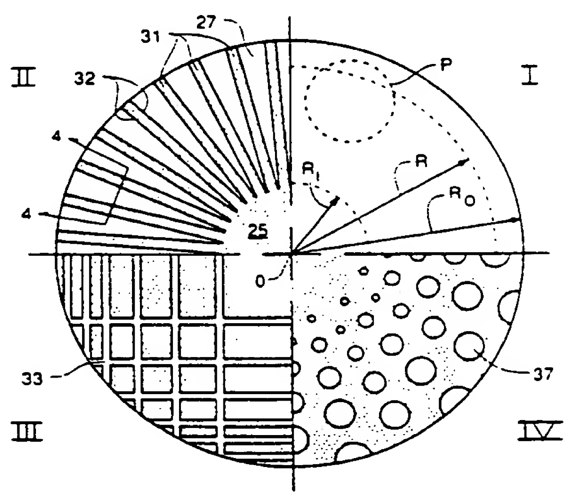

FIG.3

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EUROPEAN SEARCH REPORT

Application Number

EP 91 10 0770

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.5)
A	SOVIET INVENTIONS ILLUSTRATED Derwent Publications Ltd., section Mechanical, week 8635, abstract no. 231126, P61, 12 September 1986; & SU - A - 1206067 (SAPFIR RES INST) 23.01.1986	1	B 24 B 37/04
A	FR-A-1 195 595 (MASSON) * page 2; figure 3 *	1	
X		4,5	
A	US-A-4 244 775 (D'ASARO) * claims 1,6; column 3, lines 32-54; figures 2,3 *	1,3,6,9	
A	PATENT ABSTRACTS OF JAPAN vol. 1, no. 24 (M-76), 26 March 1977, page 1865; & JP - A - 51137998 (HITACHI SEISAKUSHO) 29.11.1976	1,5	
A	FR-A-2 063 961 (LA RADIOTECHNIQUE-COMPELEC) * claim 1; page 4; figures 1-3 *	1,6,9	
A	EP-A-0 318 135 (MAGNETIC PERIPHERALS) * claim 1; column 5, line 30 - column 6, line 28; figures 4,5 *	1,5	TECHNICAL FIELDS SEARCHED (Int. Cl.5)
A	PATENT ABSTRACTS OF JAPAN vol. 11, no. 316 (M-631)(2763), 15 October 1987; & JP - A - 62099072 (SUMITOMO ELECTRIC IND) 08.05.1987	3	B 24 B B 24 D H 01 L

The present search report has been drawn up for all claims

Place of search	Date of completion of search	Examiner
Berlin	21 November 91	MARTIN, A.

CATEGORY OF CITED DOCUMENTS

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